THE BARN OWL EGG: WEIGHT LOSS CHARACTERS, FRESH WEIGHT PREDICTION AND INCUBATION PERIOD

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Abstract. — A total of 177 Common Barn-Owl (*Tyto alba pratincola*) eggs produced by 14 captive pairs were studied during the spring of 1985, Initial egg parameters for 75 eggs were fresh weight (26.6 ± 1.4 g), length (43.07 ± 1.24 mm) and breadth (33.67 ± 0.70 mm). Using these data, a coefficient (K_W) unique to the barn owl egg was calculated for Hoyt's (1978) equation for predicting the fresh weight of an egg. (K_W = ° .0005453)

For 50 artificially incubated eggs (hatchability = 93.5%) the lay to pip (LP) interval was 28.2 ± 1.4 d, the pip to hatch (PH) interval was 2.1 ± 0.5 d and the overall incubation period was 30 ± 1.5 d. Variance in the latter period (range: 27-35 d) may have been due to an observed delay in initial embryonic development of from 1-7 d.

During incubation, several externally quantifiable changes occur in the avian egg. These include: 1) the relatively steady reduction in weight due mainly to loss of water vapor by diffusion from the embryonic chorioallantois through the porous shell and its evaporation at the eggshell surface (Romanoff and Romanoff 1949; Ar and Rahn 1980); and 2) the equal exchange of 0_2 and CO_2 gases through the eggshell by the chorioallantois - a process not affecting weight loss (Wagensteen and Rahn 1970, 1971). The mean percentage of fresh egg weight (W_0) lost during the incubation period for many avian species ranges from 12-18% (Drent 1970). Proper weight loss is correlated with hatchability and normal embryonic development (Walsberg 1980). During artificial incubation, accurate regulation of egg weight reduction is possible through a variety of methods; (Burnham 1983; Weaver and Cade 1983).

A mathematical equation (1) based upon egg length (L) and breadth (B), parameters which are invariant during incubation, was developed by Hoyt (1978) to predict avian W_0.

$$W_0 = K_W LB^2 \quad (1)$$

The coefficient (K_W) of this equation interrelates shell measurements, and may be adjusted to accommodate a single species for accurate W_0 for Peregrine Falcon (*Falco peregrinus*) eggs, and also observed a reduction in W_0 of 15 ± 2% during incubation of normal eggs. However, our study of the incubation of common Barn-Owl (*Tyto alba practincola)* eggs indicates that they cannot be precisely characterized by values developed for Peregrine Falcon eggs. Our objective was to measure barn owl egg weight loss and incubation period, and algin Hoyt's equation for this species.

Materials and Methods

The barn owl breeding colony of the Raptor Rehabilitation and Propagation Project, Inc., Eureka, Missouri, was established in 1979 and produced more than 150 juvenile owls yearly through 1986 for release into Missouri. The colony contained non-sibling breeding pairs collected from eastern North America. Each pair was housed in an outdoor mew in a natural setting and was fed daily a diet of fresh rodents *ad libitum.* Human disturbance was normally limited to 2 short intervals.

Barn Owls will naturally produce >1 clutch of 6-8 eggs during favorable seasons (Eckert and Karalus 1974), and often breed repeatedly all year in captivity (Mendenhall, pers. comm.). Thus, 2 clutches/pair of owls were assured. The first clutch produced by each pair was removed for artificial incubation and subsequent clutches were left with the parents for natural incubation.

Beginning in early January, approximatley 2 wks before initiation of barn owl breeding, each mew was entered daily by 1 or 2 workers and the nest boxes were checked for eggs. This procedure was completed at a prescribed time every morning through April to ensure that no egg was older than 24 hr when initially measured, and to minimize non-random disturbance of the adult owls. As each freshly laid (+ 0-24 hr) egg was discovered, it was weighed on an electric field balance to determine W_0, and the dimensions were measured with a Vernier caliper. Additionally, each fresh egg was marked with a graphite letter corresponding to its sequence in the clutch. No egg was ever fully removed from the nest box and adults were kept at a distance during measurement. During the subsequent incubation period, each egg was weighed every other day using similar methods.

To reduce parental stress and promote successful copulation, no eggs were collected from nest boxes prior to clutch completion (W.C. Crawford, Jr. pers. comm.). Egg laying interval was approximately 1 egg every 2-3 d, thus eggs were from 1 to 16 d old when removed from the nest for artificial incubation. Eggs were incubated in Roll-X RX2A automatic rolling incubators with a constant temperature of 37.5° C, and relative humidity of 48%. Each egg was rolled manually 180° 3x/d to supplement automatic rolling. Throughout the lay-to-pip (LP) interval, each egg was weighed and candled every other day to determine both weight loss and corresponding embryonic development. Once an embryo had pipped its shell, the egg was placed pipped side upwards in another Roll-X RX2A set at a lower temperature (35°C) but higher relative humidity (60%). Pipped eggs were not turned. During the pip-to-hatch (PH) interval, no weight measurements were made due to shell fragility and difficulty in determining weight at the instant of hatching. Infertile eggs or eggs containing dead embryos were removed from the incubators to inhibit bacterial growth.

Eggs undergoing natural incubation were weighed similarly through pipping, but only occasionally candled to reduce nest disturbance. No extra care was provided for these clutches (i.e. cleaning of nest boxes, bad egg removal, etc.) unless a shell failed

Table 1. Mean total fraction of grams W_0 lost over the 28 d lay to pip interval for Barn Owl eggs[a] incubated artifically and naturally.

INCUBATION	N[B]	$\bar{x}$	SD	MIN/MAX	CASES[C]	r[d]
Artificial	39	0.11	0.02	0.07-0.14	441	0.95
Natural	23	0.14	0.04	0.10-0.24	249	0.87

[a] Only fertile, successful hatching eggs represented.
[b] Number of eggs.
[c] Number of points used in generating r values and regression lines give Figure 1.
[d] Correlation coefficient relating cumulative fraction of W_0 lost to day of incubation.

in a fertile egg; such eggs were removed for artificial incubation and excluded from the study. To prevent cannibalism, an occasional aspect of barn owl adult-chick behavior, the amount of food provided for each mew was increased considerably following the hatch of each egg (W.C. Crawford Jr., pers. comm.).

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) (Nie et. al. 1975). A regression line developed by the least squares fit was generated plotting the cumulative fraction of W_0 lost by corresponding interval day. The resulting linear equation was used as a model (assuming 28 d LP interval) to predict the total fractional weight loss for all cases in each of the 2 incubation type categories. Other SPSS options were used to generate F-Test, t-Test, Pearson's r and Chi-squared (X^2) values and probabilities.

RESULTS

The mean total fraction of W_0 lost during the LP interval was significantly different (F = 07.05 df = $P < 0.001$) between artificially and naturally incubated eggs which hatched successfully (Table 1). High degrees of correlation were found between cumulative reaction of W_0 lost and interval day within each incubation group, implying that eggs dehydrated similarly in their respective categories although a wide range of total fraction of W_0 lost by individuals was noted.

We defined hatchability as the percent of fertile eggs successfully hatched. The hatchability of naturally incubated eggs was 80.9% (n = 62). Hatchability between incubation types was significantly different ($\chi^2 = 4.56$; df = $P < 0.05$).

The relationship between day of incubation and cumulative fraction of W_0 lost was examined (Fig. 1). An increase in the spread of points (statistically indicated by increasing standard deviations of residuals) from the regression line (Table 2), and corresponding decrease in correlation coefficients as incubation progressed through consecutive segments of LP interval were found. Both incubation types had this characteristic.

A species specific coefficient ($K_W = 0.0005453$) was determined using equation (1) for W_0 prediction and the measured values of W_0, L and B collected from 75 barn owl eggs (Table 3). Using this K_W a strong correlation was found between directly

Table 2. Increasing deviation of points from regression lines indicated by increasing standard deviation of residuals and decreasing correlation between fresh W_0 lost and incubation day.

INCUBATION	CASES[A]	r	P	RESIDUAL SD
Artificial				
0-10 days	136	0.83	≤0.001	0.7906
11-19 days	133	0.77	≤0.001	1.0272
20-30 days	172	0.67	≤0.001	1.2954
Natural				
0-10 days	101	0.75	≤0.001	1.3191
11-19 days	85	0.66	≤0.001	2.2498
20-30 days	56	0.29	≤0.01	3.9209

[a] Number of points used in generating the r values and regression lines given Fig. 1.

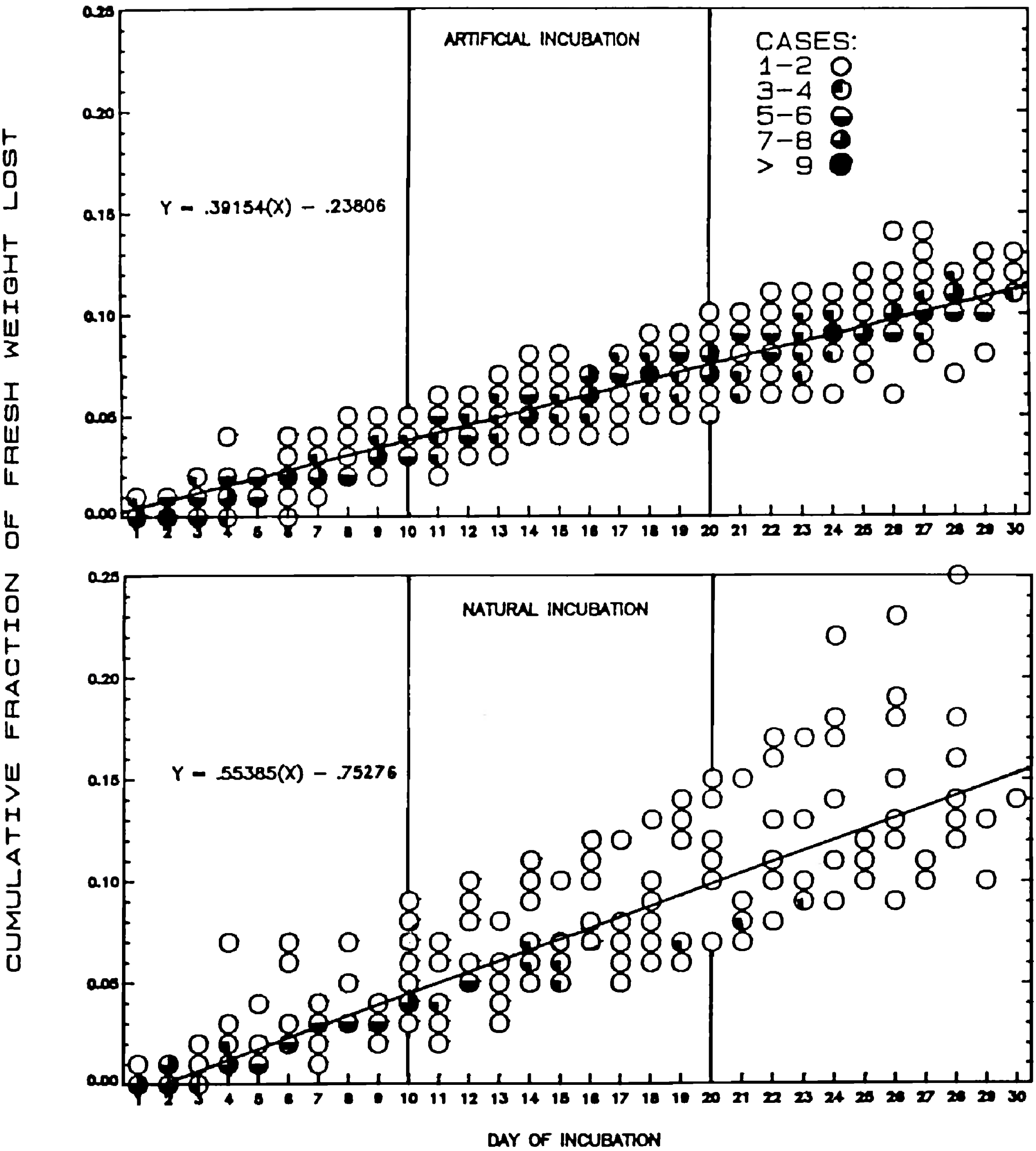

Figure 1. Regression of cumulative fresh weight lost in barn owl eggs by day of incubation.

Table 3. Summary of physical parameters from natural incubation and period of incubation for common Barn-Owl (*T.a.pratincola*) eggs incubated artifically.

PARAMETER	N	$\bar{x}$	SD	MIN/MAX
Length (l) (mm)	75	43.07	1.24	39.95-47.95
Breadth (B) (mm)	75	33.67	0.70	32.50-35.40
Fresh Weight (W_0) (g)	75	26.6	1.4	24.6 -29.9
Lay to Pip (LP) Interval (days)	50	28.2	1.4	25-33
Pip to Hatch (PH) Interval (Days)	50	2.1	0.5	1-4
Incubation Period (days)	50	30.3	1.5	27-35

measured and calculated values of W_0 ($r = 0.917$; $P < 0.001$); the 2 group means were similar (t-Test = 0.39; $P = 0.701$).

When the coefficient K_W ; 0.0005474 developed by Burnham (1983) was used in equation (1), strong correlation ($r = 0.917$; $P < 0.001$) was also evident between measured and calculated values of W_O, although statistical confidence in the similarity between the 2 group means was decreased (t-Test = 1.86; $P = 0.067$).

DISCUSSION

The total incubation period of the barn owl can be generalized from the literature as 30-33 d, with extremes of 29 and 34 d (Eckert and Karalus 1974; Bunn et. al. 1982). Our study indicatd a similar mean incubation period and range.

The mean W_0 value (Table 3) of the barn owl eggs studied is inconsistent with the mean (W_0) developed from the single random sample collected (from the wild) by Sumner (1929), and his values were reported in other works (Drent 1970; Ar and Rahn 1980). However, Hoyt (1978) noted that intraspecific variability in the values of W_0, *L and B could be expected and we have attempted to account for such deviation through relatively large samples collected from many pairs of owls within the subspecies T. a. pratincola.*

Careful, frequent illumination of eggs with cool, high intensity light provided good visual tracking of embryonic development. A small fraction of embryos did not achieve the visible blastodisc stage (indicative of fertility) for up to 7 d following the date of laying. However, most embryos apparently began their development immediately, and showed a blastodisc within 24 hr. A sharp increase in the rate of egg weight loss in conjunction with abrupt initialization of embryonic development in dormant-fertile eggs was routinely observed. After an extremely low rate of daily weight loss, these eggs suddenly achieved a relatively constant rate of weight loss which continued for about 28 d until a normal fraction of W_0 was lost. The chicks then pipped the eggshell. Thus, a specific weight loss rate occurred for the latter portion of the LP interval, although this interval may have been initially extended by the dormant-fertile condition. Since the PH interval was fairly constant, with variance probably due to observational error, nearly all deviation in the barn owl incubation period was due to the initial dormant-fertile egg. It was unclear whether the dormant-fertile condition was random or relative to other eggs' development within clutches, but eggs generally hatched in sequence of their laying. Quantification of this embryological characteristic was not possible using their sample and further study is required.

Although hatchability and mean total fraction of W_0 lost was related to incubation type (natural *vs* artificial), the 2 incubation methods are very differently affected. Factors inherent only during natural incubation include frequent variation in nest microclimate and ambient temperature and humidity, high bacterial exposure, and violent movement of delicate eggs by disturbed adult owls. Such relatively uncontrollable variables may have caused natural incubation weight loss rates to occur which do not parallel those of eggs in undisturbed nests. These adverse factors undoubtedly contributed to the lower hatchability of fertile eggs undergoing natural incubation, although the sample analyzed includes many eggs from undisturbed nests.

Regression of weight lost by interval day reveals an increase in deviation between predicted and actual egg weights during the LP interval. Since weight loss is due to expired water vapor, as previously cited, this unexpected trend may reflect differential individual respiratory function, effected by the chorioallantois in conjunction with the eggshell, which was not subject to purely passive diffusion. This result contrasts with recent literature which cites simple diffusion down concentration gradients as the single force moving gases across the eggshell (Wangensteen and Rahn 1970, 19721).

Inferences drawn from these results are interesting to both the ecologist and the conservationist propagating this species artifically. *Tyto alba* supp. possess extremely favorable reproductive capabilities. Developmental flexibility is reflected in the variable egg weight losses achieveable during incubation and in the dormant-fertile condition which allows extension of incubation period. These factors may contribute to the high hatchability evident from the data in this study.

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